Cross-system log file analysis for hypothesis testing

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Understanding the effects of different functionality in complex learning environments is one of the key challenges of learning technology research. Particularly for new personal learning environments which combine a variety of services to offer new educational approaches such comparisons become increasingly important for analysing the effects compared to established learning environments. This paper discusses the use of cross-system log file analysis for enabling the comparison between different logging approaches used either by different PLE components of different systems used in evaluation. . In the presented example the results of a cross-system log file analysis are also used for validating the results of other measures as a questionnaire. This kind of validation reduces the gap of self-recognition of activities and opinions of learners, and the actual performed actions within a learning environment. This provides a more detailed picture than subjective evaluation could do alone.

Keywords: competence development, virtual learning environments, log file analysis, evaluation

Introduction

Understanding the effects of a technology for the learning process is one of the key challenges of learning technology research. Over time, this challenge has changed in its focus remarkably for complex integrated learning environments. Especially in new personal learning environments where a variety of functionality can be combined and used in different ways by the learners an analysis of the effect of the different tools and functionalities on learning becomes more difficult and requires multi-method approaches.

This shift has implications on the technical and empirical design of evaluations of virtual learning environments. This *methodological* paper describes an approach for comparing interaction footprints (as log files and others) from different systems and independent service components, and how this approach helps improving the quality of overall evaluation results. This approach is called cross-system log file analysis and is used to structure and compare user visits and navigation behaviour of virtual learning environments which services are based on different underlying software components.

Cross-system log file analysis is used within the TENCompetence project for evaluation of pilot studies. The TENCompetence project aims at the development of an European infrastructure for lifelong competence development. The underlying educational principles of learning networks and competence centred learning [2, 3] require structural changes of design and functionality of virtual learning environments in order to meet the variety of ways of competence acquisition and development in lifelong learning support. This implies that an infrastructure that supports competence centred learning needs to provide access to different types of tools than more traditional forms of technologically enhanced education and training.

The TENCompetence infrastructure is validated in a number of pilots studies, representing the variety of contexts in which lifelong competence development takes place [6]. In a first cycle of pilot studies the TENCompetence infrastructure and the Moodle system have been used by different groups of learners. The participants of the pilot studies have been given pre-test and post-test questionnaires. With respect to the research questions, the participants are asked to process pre- and post-test questionnaires. These questionnaires address two main research questions.

- Does the freedom of choice and the tools to handle that freedom, which are offered by the TENCompetence infrastructure, lead to better outcomes than the rigid structures

provided by traditional education?
- To what extent are the tools, which are provided by the TENCompetence infrastructure, helpful in managing this freedom once learners can choose their own learning path and resources?

Pre- and post-test questionnaires provide information about the subjective value or usability of the involved system components but do not provide information about the actual use of a system or combined usage of certain functionality. Furthermore the subjective information is biased by awareness of the participants. Therefore we analyse the actual usage of the systems in order to develop a better understanding of the relation of the participants' perception and use of each system component. For this purpose the access logs of the TENCompetence infrastructure and the Moodle system are analysed, because these logs contain data about all interactions, which the participants performed during the pilot study. Nevertheless the Moodle system and the TENCompetence system component use different logging metrics and protocols therefore we had to develop a methodology to make the log files comparable. In the following we describe the steps and main methods which have been developed and implemented to do so.

What are log files?

Log files are transcripts of the activity of a server system. For web based systems, the server system is the web server including all components that made available through it. These components can be CGI scripts (e.g. written in PHP) or web services that make more extensive use the server's internal functions.

For web-applications there are basically two different types of log files. The first type of log files is the so called error log or message log. These logs provide insights on the internal activities of the system. Message logs depend on what is reported from the different components of the underlying system. Basically, message logs allow components to report their internal activities in a free form format that depends on the interests and needs of the programmers of each component. This implies that available data of a component depends on what a component writes to the log. Moreover, the data found in the message logs can be in a completely unstructured format. This makes message logs suitable for debugging components of a system.

The second type of log files is the access log. Access logs are used by web servers to report any request that had been made to the system. These log files provide data about the external activities of a system. For web servers these logs contain data about the requests issued by web browsers or similar systems to a web server. The data that is stored in the access logs is mostly independent from the component that actually served a request. More importantly, the data stored in access logs is clearly structured and well defined. For web systems there exists a limited set of standardised structures for access logs[1]. These structures commonly include the source of the request (the host name or IP address of the machine on which the web browser runs), the type of request, the requested URL, the user name of authenticated users, and the success state of a request. Such standardised structures make the access logs suitable for statistical analysis about the actual usage of a system. Therefore, there is a long tradition of the analysing access logs in order to infer knowledge about the actual use of web-based systems [1, 4, 5, 7, 8].

Some information in the access logs depends on the components that handle the particular request. This is particularly the case with user information. Many scripting frameworks make no or little use of the mechanisms of the underlying web-server for reporting authenticated users back to the server. I.e. the user information of authenticated users is not stored in the access logs, although users authenticate with systems that use such frameworks. Interestingly, some systems replicate the server system's logging facilities. An example for such a replication is the internal access log of the Moodle system. If such component specific access logs are available, it can be (partially) converted into the standardised log formats because they provide basically the same information as the server system's access logs [5].

Cross-system log file analysis

Previous research on log file analysis has focussed either on the usage of a system, on the usage of variations of the same system, or on the comparison of low level access statistics of different systems, which is often based on outputs of tools, such as analog[2] or webalizer[3]. The approach of cross-system log file analysis

[1] http://httpd.apache.org/docs/2.2/logs.html
[2] http://www.analog.cx/
[3] http://www.mrunix.net/webalizer/

that is discussed in this paper, addresses the retrieval of higher level information about the actual use of systems with structural differences. This requires some homogenisation of the access logs as well as more knowledge about interaction patterns of each system that is included in the analysis. Therefore the cross-system log file analysis has two steps: 1) the log file normalisation, 2) the action analysis.

Log file normalisation

While comparing access logs of different systems, log file normalisation is required in order to have homogeneous data sources. This step is always required if the systems use structurally different access mechanism to store interaction footprints to their logs, which is the case with the TENCompetence Infrastructure and the Moodle system. The normalisation aims at the harmonisation of the log files of the two systems. Without this step the different log files will lead to incomparable data sets.

The log file normalisation can be conducted on two levels either on the user-session or the activity type.

At the level of user session, the normalisation separates all sessions of different users. A session includes all requests from one IP address that were handled within a given timeframe. The duration of that time frame is defined by the time that has passed between two requests. If two requests from the same IP address were handled within a time limit, the two requests are treated as part of the same sessions; otherwise they belong to different sessions. However, IP address and time limit are not sufficient in environments such as Internet cafés or computer labs in universities. For that purpose the user name has to be used as an additional constraint, i.e. if two requests from the same IP address were performed within a time frame but associated with different user names, the requests belong to different sessions.

At the level of activity types, the normalisation isolates the tools offered by the virtual learning environment and removes all but one request of an action sequence. An action sequence covers all accesses to the same tool which are not separated by requests to another tool. Non sequential requests to the same tool remain unaffected by this step. After the activity type normalisation each usage of a tool of a system is represented by one request. This eliminates the differences of the systems which are the results of differences in the underlying system architecture. Because these implementation dependent differences are removed, it is possible to compare the user sessions of the different systems directly.

Normalising regarding the activity types depends on the ability for identifying the activity types. This requires knowledge where the different systems store the information about the activity types in their log files. For the TENCompetence infrastructure this information can be found encoded in the URI of an action, while Moodle stores this information as part of the “action” field of the log database. Together with this information both system store also the kind of action, i.e. if a user contributed information (such as posting to a forum) or if a user was just accessing the information provided by that tool (such as downloading a resource form the document repository). The log file normalisation has to take care that contributing and reading information can be identified in both systems, separately.

Action analysis

After the log file normalisation the different components of the system, it should be possible to compare all information from the log files of both systems directly. In practice this is not always possible, because there is no standard naming convention for the different tools in learning environments. Therefore an additional alignment of the tool names of the systems is required. This tool alignment already highlights where the systems have structural differences. Table 1 shows the tool alignment for the TENCompetence infrastructure and the Moodle system as they were detected in the log files of the pilot studies that have been already conducted. From this table it becomes visible that tools related to competence development are specifically to the TENCompetence infrastructure, while the tools forum, item, and action are only available in one of the systems.

Given to the structure of the normalised log files, the analysis of the systems can be conducted on four levels: 1) Tool level, 2) User level, 3) Session level, 4) Time level.

On these levels a direct comparison of the log files can be performed by using descriptive statistics, i.e. it is possible to compare the absolute and relative values from both systems. These descriptive statistics provide information on the following dimensions.

- Access times
- Actual users
- Independent sessions

- Overall tool usage
- User activity (number of different activities per session)
- Frequency of system use of returning users
- Drop out
- Frequency of tool usage (total and per session) per user
- Session structure
- Changes of the session structure over time

While log file analysers are already capable to provide descriptive statistics on these dimensions, the initial log file normalisation is required to understand the differences in using the investigated systems.

Table 1 Relations of the tool names of the TENCompetence infrastructure and Moodle

TENCompetence Infrastructure	Moodle
registration	course + enrol
action	?
assessment	assignment
competencedevelopmentplan	course
competenceprofile	-
competences	-
item	?
resource	resource
user	user
?	forum

Cross-system log file analysis for hypothesis testing

The purpose of the approach is not to provide descriptive statistics of the system usage, but to use these statistics for hypothesis testing. In order to do so, the research questions need a translation into the dimensions that are found in the log files, and a definition of expectations on what will be detected in the log files of the different systems with regard to the related dimensions. In the following it is shown how this is done for the two key research questions of the TENCompetence pilot studies that have been introduced earlier in this paper.

The first research question addresses the structuring and the quality of the learning processes. The question has two core implications regarding the user behaviour: firstly, the "freedom of choice" implies that users will take advantage of this freedom and use the available tools more freely according to their actual learning needs; secondly, the question assumes improvements of the learning outcomes. The first part of the question can be directly related to the *session structure* and the *user activity*. The second part of the question is more difficult to translate into activity patterns. There are two dimensions of the log file analysis that can get used as quality measures: the *drop out rate* and the *frequency of tool usage per user*.

For the results of the log file analysis it is expected the session structure differs significantly for the users of the two systems. Therefore it is expected that Moodle users will have more similar session structures because of the more rigid curricular approach, while the users of the TENCompetence infrastructure show greater variations in their session structures because of the freedom that is provided by that environment. Furthermore, it is expected that the users of the TENCompetence infrastructure use a greater variety of tools, compared to those users of the Moodle system. Regarding the quality measures fewer drop outs and more frequent use of the different tools is expected for the users of the TENCompetence infrastructure.

The second research question for the pilot evaluation addresses the tools that are provided by the TENCompetence infrastructure specifically to support competence centred learning. This question implies that the tools, which are provided by the TENCompetence infrastructure specifically for competence development, are used for planning and self-

assessing the personal competence development. In terms of user actions this is reflected in the log files on the dimensions *tool usage*, *session structures*, and the *changes of session structures over time*.

With regard to these dimensions it is expected that the majority of the users of the TENCompetence infrastructure use the competence profile and competence information tools for planning their learning paths, and the users frequently use theses tools for organising and managing their learning activities. Furthermore, it is expected that the structure of the user sessions changes towards more variation and more flexible use other tools, if the users make more use of the competence profiles and of the information about their competences.

Conclusions and further research

The results of the log file analysis can be used for questionnaire validation. This kind of validation reduces the gap of self-recognition of activities and opinions, and the actual performed activities within a learning environment. This provides a more detailed picture than opinion based evaluations could do alone. For example, users may report that they appreciate the availability of a certain tool, but they never use it during their learning activities, or the other way around. Therefore, the log file analysis can be used as an instrument that puts the results of a questionnaire study in direct relation with the actual user behaviour.

The differences between virtual learning environments and the variation of complex usage patterns regarding their impact on the actual learning processes have received little attention by recent research. Particularly, for software systems, which offer new approaches to learning, such comparisons become increasingly important for analysing the benefits compared to established learning environments. This paper discussed the use of cross-system log file analysis for estimating the quality of the results from other empirical evaluation methods with regard to the hypothesises under investigation.

Further research on this approach heads towards two directions. First, it has to be analysed to what extend the results of a cross-system log file analysis can verify the results of pre -and post-test based evaluations methods. Second, it has to be investigated to what extend cross-system log file analysis can be applied for analysing networked learning environments in which different systems and services facilitate a unique learning experience. This second research thread will become of greater interest as Web2.0 techniques will become more important in the organising the functions of virtual learning environments.

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